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Key to Species and Varieties of Ferns and
Fern Allies of Northeastern
North America
RAY C. FRIESNER

A Phytosociological Study of the Herbaceous
Plants in Two Types of Forests in
Central Indiana

J. E. POTZGER and RAY C. FRIESNER

What is Climax in Central Indiana?
A Five-mile Quadrat Study

J. E. POTZGER and RAY C. FRIESNER

Some Necessary Nomenclatorial Changes
in the Genus *Solidago*
RAY C. FRIESNER

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11. Certain aspects of the H-ion concentration of the soils of a certain Indiana river bluff, by Stanley A. Cain and Ray C. Friesner. Pp. 172-175. October, 1930.
12. A microtome knife cooler, by Ray C. Friesner. P. 176. October, 1930.
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2. The acid ranges of some spring-flower herbs with reference to variations in flower color, by Rexford F. Daubenmire. Pp. 25-28. August, 1931.
3. Factors favoring the persistence of a relic association of eastern hemlock in Indiana, by Rexford F. Daubenmire. Pp. 29-32. August, 1931.
4. Fat deposits in certain Ericaceae, by Oran B. Stanley. Pp. 33-44. August, 1931.
5. Chromosome numbers in *Fagus grandifolia* and *Quercus virginiana*, by Hellen Aufderheide. Pp. 45-52. October, 1931.

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KEY TO SPECIES AND VARIETIES OF FERNS AND FERN ALLIES OF NORTHEASTERN NORTH AMERICA

By RAY C. FRIESNER

The publication of Broun's¹ "Index to North American Ferns" has filled a long-felt need for students of pteridophytes. The frequent changing of names of plants is not only confusing to students but annoying to teachers as well, when they must learn a new name every year and perhaps carry several names in their mind at once in order to meet the needs of students using different keys and manuals. Broun's book will go far toward stabilizing a recently vacillating field of taxonomy and is essential in every laboratory where pteridophytes are studied and taught.

With the matter of nomenclature and synonymy settled for a while, the next demand for teaching taxonomy of this group is a convenient manual and key for student use. No manual is available for all of the species and varieties occurring in northeastern North America but we have found Wherry's² "Guide to Eastern Ferns" most suited for our purposes. This excellent little manual contains a key. Consequently, it was necessary to construct our own key for student use.

The following key is aimed at enabling students to determine the species and varieties of pteridophytes given by Broun for northeastern North America (what is commonly thought of as the "Gray's Manual range"). It makes no claim to originality in the choice of differentiating characters and to the host of students in this field from whose published writings material has been taken, credit is here acknowledged. Following each name are given page references in Gray's Manual, 7ed. (G), Wherry's Manual (W), and other references when the plant is not to be found in either of these manuals.

In order that teachers may have this key available for student use, prints of this paper are available at ten cents per copy and may be secured from the Botany Department of Butler University.

KEY

- | | |
|--|---|
| 1. Plants floating on the surface of boggy waters..... | 2 |
| 1. Plants not floating..... | 3 |

¹Broun, Maurice. Index to North American Ferns. Published by the author, Orleans, ss. 1938.

²Wherry, Edgar T. Guide to Eastern Ferns. Science Press. 1937.

2. Leaves apparently 2-ranked, densely papillose on dorsal surface *Salvinia natans* (L.) All. G 50
2. Leaves closely imbricated, glabrous on dorsal surface *Azolla caroliniana* Willd. G 50; W 47
3. Plants twining or climbing *Lygodium palmatum* (Bernh.) Sw. G 46; W 43
3. Plants neither twining nor climbing..... 4
4. Plants very slender, filiform, tortuous..... *Schizea pusilla* Pursh. G 45; W 45
4. Plants neither filiform nor tortuous..... 5
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5. Leaves reduced to mere vestigial scales whorled at the nodes of jointed stems (*Equisetum*) 152
5. Leaves very long and narrow, 3-20 cm long by 0.5-1 cm wide, very closely imbricated on a short corm-like stem (*Isoetes*) 166
5. Leaves very small, 2-10 mm long, very closely imbricated (*Lycopodineae*) 7
5. Leaves larger, broader, frond-like (common true ferns).. 35
6. Leaflets glabrous; sporocarps 2-3; peduncle attached to petiole *Marsilea quadrifolia* L. G 50; W 47
6. Leaflets hairy; sporocarps solitary; peduncle free from petiole *Marsilea vestita* Hook. & Grv. G 50
7. Homosporous, i. e. spores and sporangia of one type only.. 8
7. Heterosporous, i. e. spores and sporangia obviously of two sizes 33
8. Spore-bearing leaves not aggregated into definite strobili or cones 9
8. Spore-bearing leaves aggregated into definite strobili.. 12
9. Leaves in alternating zones of longer and shorter lengths.. 10
9. Leaves uniform in length, i. e. not in alternating zones of longer and shorter lengths *Lycopodium selago* L. G 55; W 161
10. Leaves broadest near or above their middle 11
10. Leaves broadest at their bases..... *Lycopodium selago patens* (Beauv.) Desv. G 55; W 163
(*L. lucidulum porophilum* in Gray Man. 7ed.)

1. Leaves definitely serrate
.....*Lycopodium lucidulum* Mx. G 55; W 165
1. Leaves entire or only slightly serrate
.....*Lycopodium lucidulum occidentale* (Clute) Wilson. G 55; W 165 (Rhodora 34:170. *L. l. porophilum* in Gray Man. 7ed.)
12. Sporophylls, i. e. the leaves comprising the strobili, not conspicuously different in appearance from the vegetative leaves 13
12. Sporophylls yellowish and scale-like, very different in appearance from the vegetative leaves 17
3. Sporophylls 7-10 mm long 16
3. Sporophylls 5-6 mm long 14
14. Sporophylls deltoid, mostly entire 15
14. Sporophylls suddenly contracted above the base into a narrow subulate apex, more or less toothed near base ..*Lycopodium adpressum* (Chapm.) L. & U. W 183
5. Fertile branches 3-10 cm high
.....*Lycopodium inundatum* L. G 56; W 179
5. Fertile branches 1-3 dm high*Lycopodium inundatum bigelovii* Tuckerm. G 56; W 179
16. Median sporophylls 0.75-1.25 mm wide at base, beset with 6-10 or more bristle-like teeth rather evenly distributed from the base upwards to beyond the middle..*Lycopodium alopecuroides* L. G 55; W 181
16. Median sporophylls about 1.5 mm wide at base, beset with 4-6 marginal teeth or bristles clustered between the spore case and the middle of the sporophyll....
.....*Lycopodium inundatum robustum* R. J. Eaton. W 179; Rhodora 33: 202.
7. Leaves on the vegetative branches about uniform in length all the way around the stem, giving the branch as a whole a nearly cylindrical appearance (except for flattening due to pressing in the case of herbarium material) 18
7. Leaves on the vegetative branches longer on the sides than on the top and bottom of each branch, giving the branch a more or less flattish appearance 26
18. Free (i. e. unattached) portion of leaves 1-3 mm

- long; leaves in 5 rows
.....*Lycopodium sitchense* Rupr. G 56
18. Free portion of leaves 4-8 mm long; leaves in more than 5 rows 19
19. Strobili sessile at the ends of leafy branches, i. e. not lifted above vegetative portions of stem on peduncles differing conspicuously from the vegetative branches 20
19. Strobili lifted above the vegetative parts by slender peduncles containing modified scale-like leaves 23
20. Erect stems dendroid, i. e. tree-like in their branching
.....*Lycopodium obscurum dendroideum* (Mx) D. C. Eaton. G 56; W 171
20. Erect stems simple, not at all dendroid 21
21. Leaves appressed
.....*Lycopodium annotinum pungens* Desv. G 56
21. Leaves spreading 22
22. Leaves lanceolate to oblanceolate, distinctly serrate, thin
.....*Lycopodium annotinum* L. G 56; W 167
22. Leaves linear or lance-attenuate, entire or slightly serrate, thickish
.....*Lycopodium annotinum acrifolium* Fern. Rhodora 17:124
23. Strobili one per peduncle 24
23. Strobili two per peduncle 25
23. Strobili three or more per peduncle
.....*Lycopodium clavatum subremotum* Vict. Contr. Bot. Lab. Univ. Montreal 3:24. 1925
24. Peduncles 1-2.5 cm long
.....*Lycopodium clavatum monostachyum* Desv. G 56
24. Peduncles 3-15 cm long
.....*Lycopodium clavatum megastachyon* Fernald & Bissell. Rhodora 12:53
25. Strobili sessile on the peduncle
.....*Lycopodium clavatum* L. G 56; W 169
25. Strobili on short secondary peduncles (pedicels)
.....*Lycopodium clavatum laurentianum* Vict. Contr. Bot. Lab. Univ. Montreal 3:23. 1925
26. Strobili borne sessile at the ends of leafy branches..
.....*Lycopodium obscurum* L. G 56; W 173
26. Strobili lifted above the leafy branches on definite peduncles 27

27. Peduncles arising direct from horizontal stems or rootstocks *Lycopodium carolinianum* L. G 56; W 185
27. Peduncles arising from tips of erect branches 28
28. Free portion of lateral leaves nearly as long as the adnate portion 29
28. Free portion of lateral leaves not over 1/2 as long as the adnate portion 30
29. Peduncles 1.5-4 cm long
..... *Lycopodium sabinaefolium* Willd. G 56
29. Peduncles 6-7.6 cm long *Lycopodium sabinaefolium sharonense* Blake. Rhodora 20:60
30. Branches somewhat glaucous, bluish-green in color; branch plus adnate portion of leaves 1-1.5 mm wide; ventral median leaf reaching or over-lapping the next one above it
..... *Lycopodium tristachyum* Pursh G 57; W 175
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31. Peduncles averaging 7 cm long; strobili mostly 4 per peduncle *Lycopodium flabelliforme* (Fern.) Blanch. G 57; W 177
32. Strobili sessile on the peduncle; rootstock superficial.
..... *Lycopodium complanatum* L. G 56; W 177
32. Strobili on short pedicels; rootstock deep
..... *Lycopodium complanatum elongatum*
Vict. Contr. Lab. Bot. Univ. Montreal 3:72. 1929
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33. Dorsal and ventral leaves shorter than the lateral.
..... *Selaginella apoda* (L.) Spring. G 58; W 189
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.. *Selaginella rupestris* (L.) Spring. G 57; W 187
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..... *Botrychium lunaria minganense* (Vict.) Dole. Mem. Torr. Bot. Cl. 19:67. 1938
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..... *Botrychium lunaria* (L.) Sw. G 48
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61. Sori covered with an indusium. (Forms in which the indusium drops when young may be sought either here or in the preceding subdivision of this step in the key.).. 70
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..... <i>Notholaena dealbata</i> (Pursh) Kuntze. G 35	

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88. Sori markedly crescent-shape
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95. Sori occurring throughout most of the length of the
frond ..*Phyllitis scolopendrium* (L.) Newman (*Scolo-
pendrium vulgare* in Gray Man. 7ed.) G 40; W 115
95. Sori limited to the upper half of the frond.....*Phyllitis
scolopendrium americana* Fern. Rhodora 37:220. 1935
96. Stipe black or purplish, or shining brown (not dull
brown) 97
96. Stipe green, straw-color, or dull brown 105
97. Frond pinnatifid, or if pinnate, only so at base
.....*Asplenosorus ebenoides* (Scott) Wherry.
(*Asplenium ebenoides* in Gray Man. 7ed.) G 38; W 111
97. Frond truly pinnate 98
98. At least the lower pinnae more or less auricled 99
98. Pinnae not auricled 104
99. Lower pinnae more or less pinnatifid 100
99. No pinnae pinnatifid 101
100. Margins of pinnae serrate or dentate.....
.....*Asplenium bradleyi* D. C. Eaton. G 39; W 99
100. Margins of pinnae crenateX *Asplenium
stotleri* Wherry (A hybrid, *A. pinnatifidum* x
A. platyneuron) Amer. Fern Jour. 15:52. 1925
101. Rachis green, different in color from stipe....*Asplenium
kentuckiense* McCoy. Am. Fern Jour. 26:104. 1936
101. Rachis black and shining, same as stipe 102
102. Pinnae mostly opposite ..*Asplenium resilens* Kunze
(*A. parvulum* in Gray Man. 7ed.) G 39; W 95
102. Pinnae mostly alternate 103
103. Median pinnae 1-3 cm long; sori confluent in age
.....*Asplenium platyneuron* (L.) Oakes. G 38; W 97
103. Median pinnae 5-8 cm long; sori not confluent in age....

-*Asplenium platyneuron bacculum-rubrum*
 (Featherm) Fern. Rhodora 37:382. 1935; 38:304. 1936
104. Rachis black. *Asplenium trichomanes* L. G 38; W 93
104. Rachis green. X *Asplenium gravesii* Maxon. W 109
105. Frond (blade plus stipe) short, 3-25 cm long. 106
105. Frond long, 4-15 dm long 110
106. Blade pinnatifid, or pinnate at base only. 107
106. Blade 1-pinnate throughout
*Asplenium viride* Huds. G 38
106. Blade 2-4-pinnate 108
107. Blade pinnate in lower half, pinnatifid in upper half. 107a
107. Blade pinnatifid throughout, not at all pinnate.
*Asplenium pinnatifidum* Nutt. G 38; W 107
- 107a. Lowermost pinnae mostly opposite
X *Asplenium trudellii* Wherry W 105
- 107a. Lowermost pinnae mostly alternate
*Asplenosorus inexpectatus* Braun (Braun,
 E. Lucy, Amer. Fern Jour. 29:133-135. 1939.
 Above name supplied in private correspondence
 by Miss Braun and here used for the first time.)
108. Stipe brown below, green above
*Asplenium montanum* Willd. G 39; W 103
108. Stipe green throughout 109
109. Pinnae lanceolate with incised margins and long attenuate
 tips *Asplen-*
ium cryptolepis ohionis Fern. Rhodora 30:43. 1928
109. Pinnae narrowly cuneate to roundish-obovate, not at all
 attenuate
*Asplenium cryptolepis* Fern. G 39; W 101
110. Frond 1-pinnate *Diplazium*
pyncocarpon (Spreng.) Broun (*Asplenium ang-*
ustifolium in Gray Man. 7ed.) G 39; W 85
110. Frond 2-pinnatifid *Diplazium*
thelypteroides (Mx.) Presl. (*Asplenium acros-*
tichoides in Gray Man. 7ed.) G 39; W 87
110. Frond 2-4-pinnate 111
111. Fronds coriaceous 112
111. Fronds herbaceous, not coriaceous 113
112. Fronds 2-pinnate to somewhat 3-pinnatifid; ultimate
 subdivisions mostly approximate; sori median or

- sub-median *Athyrium*
alpestre (Hoppe) Rylands. Rhodora 30:48. 1928
- 112 Fronds 3-pinnate to 4-pinnatifid; ultimate subdivisions distant; sori chiefly submarginal. . *Athyrium*
alpestre gaspense Fern. Rhodora 30:48. 1928
113. Stipe very short, densely clothed with persistent scales; sori only slightly longer than wide
..... *Athyrium filixfoemina*
sitchense Rupr. Moore, Index Filicum 183. 1860
113. Stipe 0.25 to 2 times the length of the blade; scales few and early deciduous; sori definitely longer than wide.. 114
114. Blade widest nearer the base than the middle; the second pair of pinnae only slightly shorter than the first pair *Athyrium*
asplenioides (Mx.) Eaton (*Asplenium*
filix-foemina in Gray Man. 7ed.) G 40; W 91
114. Blade widest near the middle; the lowermost pinnae much shorter than the median 115
115. Sori at maturity confluent over the lower surface of the pinnule 116
115. Sori at maturity not confluent 118
116. Fertile pinnules deeply and sharply toothed, acute..
..... *Athyrium angustum*
boreale Jennings. Am. Fern Jour. 8:82. 1918
116. Fertile pinnules shallow-toothed, obtuse 117
117. Lowest pinnae of fertile frond 5-12 cm long; pinnules 4-12 mm long, simple
..... *Athyrium angustum* (Willd.) Presl. (*Asplenium*
filix-foemina in Gray Man. 7ed.) G 41; W 89
117. Lowest pinnae of fertile frond 10-20 cm long; pinnules 12-25 mm long, pinnatifid..... *Athyrium angustum*
elatium (Link) Butters. Rhodora 19:191. 1917
118. Pinnules lanceolate; membranous wing along rachis of pinnae obscure or wanting 119
118. Pinnules oblong; membranous wing along rachis of pinnae strongly developed.... *Athyrium angustum*
laurentianum Butters. Rhodora 19:194. 1917
119. Indusia long-ciliate; pinnules sharply acute
..... *Athyrium angustum glanduliferum* Jennings. Am. Fern Jour. 8:82. 1918

119. Indusia obscurely ciliate; pinnules only subacute.....
.....*Athyrium angustum*
rubellum (Gilb.) Butt. Rhodora 19:193. 1917
120. Indusia attached by one side 121
120. Indusia attached at 2 or more points beneath the
sporangia, i. e. indusia inferior 126
120. Indusia attached by its center 133
121. Fronds ovate-lanceolate to oblong-lanceolate, 2-3-pinnate.. 122
121. Fronds deltoid-ovate, 3-4-pinnate....*Cystopteris montana*
(Lam.) Bernh. Underwood, Our Nat. Ferns 6ed. p119
122. Blade 1-3 dm long, not attenuate; pinnae decurrent
on the winged rachis 123
122. Blade 3-8 dm long, attenuate; pinnae not decurrent
on the wingless rachis; often bearing bulblets on
back of rachis
...*Cystopteris bulbifera* (L.) Bernh. G 43; W 79
123. Basal pinnules of lower pinnae sessile 124
123. Basal pinnules of lower pinnae with a definite margined
petiolule
.....*Cystopteris fragilis protrusa* Weatherby. W 77
124. Basal pinnules of lower pinnae unevenly cuneate at
base, from nearly orbicular to deltoid-lanceolate;
indusium relatively large, up to 1 mm long, more
or less deeply cleft at apex 125
124. Basal pinnules of lower pinnae evenly cuneate at
base, oblong to obovate, or lanceolate to oblong-
lanceolate; indusium about 0.5 mm long, shallowly
lobed or nearly entire
...*Cystopteris fragilis mackayii* Lawson. W. 75
125. Plant about 2.5 dm high; indusium glabrous
.....*Cystopteris fragilis* (L.) Bernh. G 43; W 75
125. Plant larger, up to 5 dm high; indusium sparsely and mi-
nutely glandular on the back*Cystopteris fragilis*
laurentianum Weatherby. Rhodora 37. 375. 1937
126. Indusium cup-shape, its margin only shallowly cut..
.....*Dennstaedtia punctilobula* (Mx.) Moore
(Dicksonia in Gray Man. 7ed.) G 44; W 49
126. Indusium cut into numerous narrow segments..... 127
127. Stipe obscurely articulated some distance above the base
(observed as a dark irregular ring encircling the stipe). 128

127. Stipe not articulated 130
128. Stipe and ventral surface of blade densely rusty-chaffy
 *Woodsia ilvensis* (L.) R. Br. G 44; W 69
128. Stipe and ventral surface of blade not densely rusty-chaffy, glabrous or nearly so 129
129. Blades oblong-lanceolate, 16-24 mm wide
 *Woodsia alpina* (Bolton) S. F. Gray. G 44
129. Blades linear, 8-16 mm wide
 *Woodsia glabella* R. Br. G 44
130. Blade minutely glandular-puberulent 131
130. Blade entirely glabrous
 *Woodsia oregana* D. C. Eaton. G 44
131. Blade 2-pinnate to 3-pinnatifid
 *Woodsia obtusa* (Spreng.) Torr. G 44; W 71
131. Blade 1-pinnate to 2-pinnatifid 132
132. Blade loosely hispidulous with jointed white hairs..
 *Woodsia scopulina* D. C. Eaton. G 44; W 73
132. Blade not hispidulous
 *Woodsia cathcartiana* Robinson. G 44
133. Indusium round, without a sinus 43
133. Indusium round or reniform, with a sinus..... 134
134. Lowest veins on each pinnule simple or once-forked. 135
134. Lowest veins more than once-forked 137
135. Lower pinnae gradually decreasing in size until the lowest are very small
 ..*Dryopteris noveboracensis* (L.) Gray (*Aspidium* in Gray Man. 7ed.; *Thelypteris* in Wherry) G 41; W 149
135. Lower pinnae equal or somewhat smaller than the median but not becoming less than $\frac{1}{2}$ the length of the median 136
136. Fruiting veins simple
 *Dryopteris simulata* Davenp. (*Aspidium* in Gray Man.; *Thelypteris* in Wherry) G 41; W 147
136. Fruiting veins once-forked*Dryopteris thelypteris pubescens* (Laws.) Prince (*Aspidium* in Gray Man.; *Thelypteris* in Wherry) G 41; W 145
137. Pinnae 40-60, very small, 4-8 mm broad 138
137. Pinnae fewer, larger, 1.2-9 cm broad 139
138. Pinnules crowded, lower surface of blade covered

- with scales*Dryopteris fragrans*
(L.) Schott (Aspidium in Gray Man. 7ed.) G 42
138. Pinnules subremote, lower surface of blade sparsely
scaly*Dryopteris fra-*
grans remotiuscula Komarov. Rhodora 25:3. 1923
139. Sori marginal.....*Dryopteris marginalis* (L.) Gray
(Aspidium in Gray Man. 7ed.) G. 42; W 131
139. Sori not marginal 140
140. Basal scales lance-linear, caudate-attenuate.....
.....*Dryopteris filix-mas*
(L.) Schott (Aspidium in Gray Man. 7ed.) G 42
140. Basal scales lance-oblong, ovate-oblong, or deltoid,
not attenuate 141
141. Basal scales thick and firm, deep chestnut-brown
.....*Dryopteris goldianum* (Hook.)
Gray. (Aspidium in Gray Man. 7ed.) G 42; W 133
141. Basal scales thin, membranous, light-brown 142
142. Blades 2-pinnatifid to 2-pinnate 143
142. Blades 3-pinnatifid to 4-pinnate 148
143. Indusium glandular-puberulent 144
143. Indusium not glandular-puberulent 146
144. Marginal teeth of pinnules spreading; sori about 1.2
mm in diameter
.....*Dryopteris bootii* (Tucerm.) Underw.
(Aspidium in Gray Man. 7ed.) G 42; W 139
144. Marginal teeth of pinnules incurved; sori 1.5-1.8
mm in diameter 145
145. Sori near the midvein.....*Dryopteris*
clintoniana (D. C. Eaton) Dowell. (*Aspidium crist-*
atum clintonianum in Gray Man. 7ed.) G 42; W 135
145. Sori about half-way between midvein and margin.....
....*Dryopteris clintoniana australis* Wherry. W 135
146. Blade conspicuously narrowed at the base.....
.....*Dryopteris cristata* (L.)
Gray (Aspidium in Gray Man. 7ed.) G 42; W 137
146. Blade scarcely or not at all narrowed at base..... 147
147. Lobes of pinnules incurved-serrate 145
147. Lobes of pinnules spinulose-dentate 148
148. The first pair of pinnules on the upper and lower

- sides of the lowermost pinnae nearly opposite,
rarely more than 4 mm apart 149
148. The first pair of pinnules on the upper and lower
sides of the lowermost pinnae 0.5-2 cm apart,
the pinnule on the lower side farthest from the
rachis and usually exceeding the pinnule next to
it 151
149. Midrib of pinnae not glandular; indusia not glandular;
the first pinnule on the lower side of the lowermost
pinnae longer than the one next to it
.....*Dryopteris spinulosa* (Mueller)
Watt. (*Aspidium* in Gray Man. 7ed.) G 43; W 127
149. Midrib of pinnae glandular near their bases; indusia
glandular; the first pinnule on the lower side of the
lowermost pinnae not longer than the one next to it... 150
150. Pinnae tending to be set at right angles to the rachis
and to taper abruptly to a long narrow point....
..... *Dryopteris*
intermedia (Muhl.) Gray (*Aspidium spinulosum*
intermedium in Gray Man. 7ed.) G 43; W 125
150. Rachis of pinnae forming an acute angle with the
primary rachis of the blade, pinnae not abruptly
narrowed at their tips*Dryopteris*
intermedia fructuosa (Gilbert) Wherry. W 125
151. Blade 4-pinnatifid below; pinnules of the second order
on the lower side of the lowermost pinnae about twice
as long as those on the upper side of the same pinnae;
indusium glabrous or sparsely glandular
...*Dryopteris campyloptera* (Kunze) Clarkson. W 129
151. Blade 3-pinnate; pinnules not as above; indusium glandular
(known only from Concord, Mass., and York Co.,
Pa.)
.....*Dryopteris intermedia concordiana* (*Aspidium*
spinulosum concordiana in Gray Man. 7ed.) G 43
152. Vegetative and fertile stems conspicuously unlike... 153
152. Vegetative and fertile stems essentially similar in
appearance 157
153. Vegetative branches simple 154
153. Vegetative branches compound 156
154. Vegetative branches 1-1.5 mm wide; sheaths of vege-

- tative branches 4-toothed 155
154. Vegetative branches 0.3-0.6 mm wide; sheaths 3-toothed
.....*Equisetum pratense* Ehrh. G 52; W 209
155. Vegetative branches spreading; teeth of sheaths on vegetative branches green or greyish
.....*Equisetum arvense* L. G 52; W 211
155. Vegetative branches ascending or erect; teeth of sheaths blackish
.....*Equisetum arvense boreale* (Bong) Rupr. Fern Bull. 7:86. 1899
156. Vegetative branches rough to the touch.....
.....*Equisetum sylvaticum* L. G 52; W 207
156. Vegetative branches smooth to the touch.....
.....*Equisetum sylvaticum pauciramosum* Milde. Rhodora 20:131. 1918
157. Cone or strobilus not tipped with a rigid point..... 158
157. Cone or strobilus tipped with a rigid point 160
158. Erect stems unbranched.....*Equisetum kansanum* Schaffner. Ohio Nat. 13:21. 1912.
158. Erect stems branched 159
159. Sheaths appressed; teeth of sheaths 18, dark brown.....
.....*Equisetum fluviatile* L. G 53; W 203
159. Sheaths loose; teeth 8, with white margins
.....*Equisetum palustre americana* Vict. (*E. palustre* in Gray Man.) G 52; W 205
160. Aerial stems tall and many-grooved 161
160. Aerial stems low, tufted, 5-10-grooved..... 163
161. Stems rough and tuberculate 162
161. Stems not tuberculate
.....*Equisetum laevigatum* A. Br. G 53; W 199
162. Ridges of stem 40 or more
.....*Equisetum prealtum* Raf. (Included in *E. hyemale* in Gray Man. 7ed.) G 53; W 197
162. Ridges of stem less than 40
.....*Equisetum prealtum affine* (Engelm.) Broun (*E. h. affine* in Gray Man.) G 53
163. Sheaths 3-toothed.....*Equisetum scirpoides* Mx. G 54
163. Sheaths 5-10-toothed 164
164. Awn-pointed tips of sheaths deciduous 165
164. Awn-pointed tips of sheath-teeth persistent

-*Equisetum trachydon* A. Br.
 (*E. variegatum jesupi* in Gray Man. 7ed.) G 54
165. Ridges of internodes 2-angled with a broad central groove
 and a double row of tubercles; sheath segments grooved
 through the base
*Equisetum variegatum* Schleich. G 54; W 201
165. Ridges rounded; sheath segments grooved only at the
 upper end, the base rounded
*Equisetum nelsoni* (A. A. Eaton)
 Schaffner (*E. v. nelsoni* in Gray Man. 7ed.) G 54
166. Leaves without either bast bundles or stomata;
 plants permanently submersed 167
166. Leaves without bast bundles but with stomata;
 plants partially submersed 170
166. Leaves with both bast bundles and stomata; plants
 emerged most of the growing season 173
167. Leaves stout, rigid, erect 168
167. Leaves slender, mostly recurved 169
168. Macrospores honeycomb-reticulated below...*Isoetes*
macrospora Durieu (*I. hieroglyphica* and *I. tucker-*
manni harveyi in Gray Man. 7ed.) G 59; W 193
168. Macrospores with distinct or anastomosing crests...
Isoetes macrospora heterospora A. A. Eaton. G 59
169. Leaves about 1 mm in diameter
*Isoetes tuckermanni* A. Br. G 59
169. Leaves about 3 mm in diameter
*Isoetes macrospora* Durieu. G 59; W 193
170. Leaves green 171
170. Leaves reddish or rarely olive-green..... 172
171. Macrospores armed with spines
*Isoetes braunii* Durieu (*I. echinospora braunii*
 and *I. e. muricata* in Gray Man. 7ed.) G 60; W 193
171. Macrospores crested or warted but without spines.....
*Isoetes riparia* Engelm. G 60; W 195
172. Macrospores averaging 410 microns in diameter;
 wall with small pits
*Isoetes foveolata* A. A. Eaton. G 60
172. Macrospores averaging 510 microns in diameter;
 wall thin and irregular
 ..*Isoetes foveolata plenospora* A. A. Eaton. G 60

173. Leaves setaceous, plants of dry situations, rarely near water's edge *Isoetes butleri* Engelm. G 61
173. Leaves not setaceous; plants growing in water 174
174. Leaves over 3 dm long; macrospores with longitudinally folded ridges
..... *Isoetes eatoni* Dodge. G 60; W 193
174. Leaves less than 3 dm long; macrospores not as above 175
175. Primary bast bundles 4, extra bundles near periphery of leaf
..... *Isoetes melanopoda* Gay & Durieu. G 61; W 195
175. Bast bundles 4, without extras 176
176. Macrospores coarsely crested *Isoetes riparia canadensis* Engelm. (*I. dodgei* and *I. d. robbinsii* in Gray Man. 7ed.) G 61; W 193
176. Macrospores merely reticulated
..... *Isoetes engelmanni* A. Br. G 61; W 191
176. Macrospores covered with short truncate single columns. *Isoetes gravesii* A. A. Eaton. G 61

A PHYTOSOCIOLOGICAL STUDY OF THE HERBACEOUS PLANTS IN TWO TYPES OF FORESTS IN CENTRAL INDIANA

By J. E. POTZGER AND RAY C. FRIESNER

The North American deciduous forest was the most magnificent and one of the most extensive of any of the forest formations in this country, and Indiana is recognized as a region where this deciduous forest was at its best. This forest was made more complex by the large number of species with wide range of potentiality for habitat sites, and which in turn has a significant influence on the herbaceous layer under the arboreal crown cover. The deciduous forest was always noted for its numerous flowering herbs, especially during the vernal aspect, but little quantitative work has been done to date on the phytosociological aspect of these herbs. Apparently little stress has been placed upon the seasonal behavior of these herbs in the two most prominent forest associations in the deciduous forest, viz. the beech-maple and oak-hickory. These two types of forests are sensitively balanced here in Indiana as pointed out (10) for Monroe County. This feature promised some interesting data with respect to the herb layer. For that reason the present paper concerned itself specifically with the herb layer in representative stands of these two types of forest. Extensive empirical observations are seldom very accurate because the eye is deceived by size and degree of showiness of flowers which will make one overlook the real situation. In order to make the study objective and as analytical as possible, the concepts frequency, density, fidelity, and coverage guided the observations of the herbs in nine stands of oak-hickory and eight stands of beech-maple located in Brown, Bartholomew and Franklin counties, Indiana. Fidelity is expressed as percentage of representation in the total number of stands of each forest type.

METHODS

Nine representative stands of oak-hickory and eight of beech-maple were selected from locations in the above named counties, where we had previously made quantitative studies of the arboreal layer (11). In each stand ten one-meter quadrats were staked off with wire stakes. These were placed in winter when vegetation was

dormant and could not influence the selection of sites. Each quadrat was separated from the other by fifty feet of interval. Tabulations of plants were made between April 30 and May 21 for spring, between July 13 and August 3 for summer, and between September 7 and 21 for autumn. A stout cord was placed around the four stakes to delimit the quadrat sharply from the surrounding territory. The forest stands were all in the more rugged part of the state where slope controls beech-maple and oak-hickory type of forest (10) and where available soil moisture is always lower and evaporation demands almost always higher in oak-hickory than in beech-maple (5).

RESULTS

Results of the study are summarized as tables I-VIII. Among the 159 species listed (table VIII) there were only three ferns. Over 90% of the species were perennials. Oak-hickory had by far the larger number of herbaceous species for all seasons of the year, being quite uniformly 50% greater than in beech-maple (table II). The same percentage difference holds true for the whole season. Spring had the larger number of species limited to one season of above-ground vegetative activity, and autumn had the least. For the entire season, oak-hickory had 126 species in its herbaceous layer while beech-maple had only 96, a difference of 25%. Frequency index was strikingly low for nearly all species (table VIII). A selection of the species with highest frequency index is shown in table III. In the oak-hickory association, *Carex picta* heads the list with 36% frequency and *Galium concinnum* with only 28% leads all species in the beech-maple association. *Carex picta*, *Cunila origanoides*, *Potentilla simplex* had the greatest density (table IV) when all seasons are considered, but *Krigia biflora* had the greatest density for one season. In the beech-maple stands *Galium concinnum* with 289, 208 and 164 plants for the various seasons outclasses all species in density except *Arisaema triphyllum* in summer (table IV). The beech-maple types of forest show a more marked seasonal control (table IV). In a general way beech-maple is more vernal-aestival while oak-hickory is more aestival-autumnal. This same tendency is indicated in table V where highest percentages of fidelity are compared.

The highest percentage of fidelity for the whole season in the oak-hickory type is shown by *Carex picta* (88-88-88), while *Cunila*

and *Potentilla* equal this for summer and autumn with *Panicum dichotomum* a close competitor (table V).

In the beech-maple stands *Galium concinnum* is the only definitely identified species with high percent fidelity. Of the 159 species present some time during the growing season in the two types of forests, only one-third have vegetative parts above ground during the whole growing season. Species showing this characteristic were equally divided among the two types of forests (table I).

The largest number of species present during any one season were recorded in summer (112) and the least in spring (99). But the largest number of species limited to one season were present in spring. More than twice the number of species were limited to oak-hickory than beech-maple.

DISCUSSION

In a study like the present one it is not always easy to select stands which will not show a tendency to merge into one another, for in a region like Indiana the least variation in vital habitat factors will swing the tree vegetation either into oak-hickory or beech-maple as the case might be. A careful analysis of the arboreal layer, therefore, is almost essential to a reliable selection of types. All of the stands involved in the present study were included in an extensive forest study to be published as a separate paper (11).

Tables VI and VII present in a summary form the vital points on the arboreal layer of the stands designated here as oak-hickory and beech-maple. The density of 628 stems and high frequency for *Acer saccharum* in the oak-hickory type are somewhat misleading as to the true status. Both of these rather high percentages are caused by a unique condition in one stand, area 39, a steep slope in Franklin County where the plateau is typically beech-maple forest but the older trees on the slope are primarily oak-hickory. Apparently the mature maples on the plateau produce abundant seeds which germinate on the slope but fail to grow to maturity, for the 430 stems listed from that station are all small trees taking little or no part in the crown cover, for this is dominated by *Quercus muhlenbergii* and *Carya ovata*. In the beech-maple stands only beech and maple have a high density and frequency while in the oak-hickory (table VI) stands three species of oak and two hickories have a frequency index of 50% or more. The same characteristics are

borne out by table VII, where the average number of stems per ten-meter quadrat are tabulated.

Turning attention to the herbaceous layer of these two types of forests, we find first of all some very striking characteristics of distribution and seasonal activity. Of the total number of species listed only about one-third are present vegetatively all year, for the spring herbs die down to the underground parts and many autumn plants do not appear above the surface until the summer season. In the second place there is also sharply controlled difference in the distribution of species in the two forest types. Oak-hickory has twice the number of species limited to that type of forest as does beech-maple. This is, no doubt, a control of light, for the more open crown cover of oak-hickory permits more species to invade that habitat.

The herbs of our deciduous forests are outstanding by a high percentage of perennials and low fern representation. Ferns in the central part of Indiana are limited more to moist ravines and wet lowlands, and really play a minor role in the more mesophytic beech-maple and oak-hickory forests. While Esten (4) reports six species of ferns for a beech-maple stand in Turkey Run State park, they are all in the lowest frequency and coverage classes.

Coverage for most species was in the lowest class so that the results for this concept have not been tabulated. For convenience, a selection was made of the species with the highest frequency index (table III), density (table IV) and fidelity (table V), for most species registered low percentages in all three concepts. This may be induced by different causes in the two forest-types. The surface in the beech-maple stands is usually marked by a thick layer of leaf mold which, no doubt, inhibits growth of many herbs, for if herbs do not get an early start they cannot well store sufficient food before the dense crown cover shuts out the light. This same factor was pointed out (6) as control in inhibition of hemlock reproduction in the deciduous forest. In the oak-hickory type only the more favored areas permit establishment of herbs, for the habitat as a whole is quite xeric so that only deep-rooted species like *Cunila*, *Carex*, *Panicum* and *Potentilla* can attain a fair degree of distribution over large areas.

Results of the present observation in beech-maple stands correlates very closely with a similar study by Esten (4) in a beech-maple stand at Turkey Run State park. In twenty-five one-meter quad-

rats she records 32 species of herbs. Our area "37" with 50 species is somewhat higher in representation while other stands have less than 32. Density, coverage, and frequency are low for most species, only four of the species recorded in her paper reach 41 to 80%. *Claytonia virginica* and *Dentaria laciniata* were two of the four species with high frequency which, again, correlates well with the present results. She, too, describes the herbaceous stratum as vernal-aestival in character.

While some species are found in both forest types, the individuality of each is indicated by the herbs in that not a single species is in the higher frequency, fidelity and density classes in both forests alike. *Galium concinnum* is the most common and most abundant of all our flowering plants in the beech-maple woods. It also differs from most of our herbs in that it maintains a fairly active above-ground vegetative function throughout the growing season. As a whole, the two types of forests differ with respect to expression of herb layer in that beech-maple is primarily vernal while oak-hickory is aestival-autumnal, indicating, again, a light control.

Habitat and plant associations and forest-types are much debated man-made terms. They are the result of an attempt to describe complex merging expressions of results of operation of natural laws. At times the cooperating or opposing factors can be isolated but usually this is not possible at all or at least only approximately so. There is a growing realization among foresters as well as plant sociologists in this country that forest-types based on cover-types does not describe biological equivalents as accurately as the ground flora does. This would be true especially in border cases between forest types. So students of forests in Europe have for the past two or three decades classified forest-types on the basis of the ground flora. One of the first attempts of major proportions in this direction in America is the work by Heimburger (7). Stanley (12) in his work in the Yale University forest, with a similar thought at classification of forests in mind, expresses doubt as to the practicability of using such forest-site indicators beyond the immediate neighborhood where such a diagnostic study has been made.

Previous and present experimental work have shown that plants have various degrees of "plasticity" to light intensity and in this respect reactions of obligate species are easier to examine than that of facultative species, and as Lundegardh (8) says, "The same thing is true of the behavior of plants towards other factors and it is

important for the ecologist to recognize constancy of behavior of different species towards the various factors of the habitat." Likewise, is the more or less constant association of two or more species not always determined by identical habitat factors but in their combination they may have the same biological value. In a forest association the dominants have a wider range of potentiality to many or all habitat factors than the more sensitive herb, thus indicating tendencies in habitat change. And so it is quite likely that all stands of beech-maple or all stands of oak-hickory are not necessarily the same as far as the habitat of the lower strata is concerned, for variation in microclimate may exert selective action on herbs which would not be sufficiently selective to go beyond the range of potentiality of the tree layer. Lundegardh (8) says, "When one comes to the detailed observation of mesophytic areas, especially when the climatic conditions are fairly uniform, the ecological problems are by no means so obvious. Without extremely careful investigations it is often impossible to say exactly how the habitat of specific plants is composed." Here may not only various chemical phenomena be mentioned but also purely physical characteristics of the soil and various aerial factors modified and influenced by the tree layer. Watt (13) found that periodic low temperature and compact soil prevented establishment of beech seedlings in English beech forests. Adamson (1) says of two similar types of oak forests in England, "The light values obtained in this series of woods are like those of Oakham Bottom, but rather higher which explains the richer and more varied flora." All this points to a possibility of variations in the herb layer of forests with the same or similar crown cover.

Our deciduous forest is a very complex and heterogenous structure, ranging from the borders of hydrophytism to that of xerophytism with a series of merging phenomena connecting them. So beech-maple and oak-hickory control habitats which in Indiana are so critically balanced that mere exposure of slope will maintain either one or the other, and herbs ought to indicate the change from one to the other before the crown cover gives expression to the habitat.

The present study most clearly shows that the herb layer in the two forest types, i. e. beech-maple and oak-hickory, is sharply divided as to species complex. Cain (3) mentions the same possibility for the herbs in the spruce and fir forests of the Great Smoky

Mountains. Lundegardh (8) suggests that this difference is due to light, soil and humidity. Here in Indiana soil moisture must no doubt be considered one of the most vital influences. South-facing slopes with oak-hickory forest-cover had 61% greater evaporation loss than north-facing slopes with beech-maple forest-cover (5, 9). The south-facing slopes had 30% less soil moisture than north-facing slopes, so that even in a year of abundant rainfall the moisture dropped below the wilting coefficient during a large part of the summer. It has been shown that these two forest types also differ as to soil acidity (5), all these are more obvious and measurable differences in the habitats but there are, no doubt, also "hidden competitions" as Braun-Blanquet and Pavillard (2) express it. The sum total of these habitat factors results in a strikingly different species complex in the herb layer of the two forest associations.

It is indicated in the present study that several types of beech-maple and oak-hickory stands were involved. The greatest difference being between the stands in the Knobs area and those of Franklin County. We could, perhaps, classify them as the *Cunila-Carex picta-Panicum dichotomum* type of oak-hickory of the Knobs area and the *Delphinium tricornis-Dentaria laciniata* type of the eastern part of the state; the *Galium concinnum-Dentaria heterophylla-Dentaria laciniata* type of beech-maple of the Knobs and the *Galium concinnum-Dentaria laciniata-Claytonia virginica* type of the eastern part of the state.

The two types of oak-hickory also differ somewhat in their seasonal aspect of the herb layer, the eastern type is more vernal while that of the Knobs is more autumnal, indicating, thus, a longer period of dryness in the Knobs area which involves even the spring season.

The study impresses one again and again with the complexity of habitat and forest-cover, especially when phytosociological phenomena of the more sensitive lower story strata are involved. It is no doubt the "hidden control" which makes such species as *Cunila origanoides*, *Dentaria heterophylla*, *Solidago bicolor*, *Carex picta* and even such tree species as *Quercus montana* so local in their distribution here in Indiana. While the present study in all its extensiveness is dwarfed by the complexities in the control of herbs, it is consummate in its differentiation in the herb dominants between oak-hickory and beech-maple. This is reflected in every phase of phytosociology investigated.

CONCLUSIONS

1. Nine stands of oak-hickory and eight of beech-maple (ten one-meter quadrats in each stand) were studied in central Indiana as to certain phytosociological phenomena of the herbaceous layer.

2. Of the 159 species present some time during the growing season, only one-third were present during the whole season.

3. Beech-maple has its most prominent herb representation in spring, oak-hickory has it in summer and autumn.

4. While some herbs were present in both types of forest, the most prominent species in either of the forest-types are strikingly different.

5. Oak-hickory has from 45 to 50% more species than beech-maple.

6. Frequence, density, fidelity show prominent correlation in the species with prominent importance.

7. Most species have a low frequency, fidelity and density percentage, which may be due to deficient soil moisture in the oak-hickory type and to heavy leaf litter and reduced light in the beech-maple stands.

8. Coverage is in the lowest class for nearly all species.

9. Over 90% of the species are perennials.

10. The study indicates that if classification of forest-types were made on the basis of herb layer, Indiana has various types of oak-hickory and beech-maple stands with similar arboreal crown cover.

TABLE I

Distribution of species over various seasons

Total number of species in both forest types	159
Species present all year in beech-maple	29
Species present all year in oak-hickory	32
Number of species in spring, all areas	99
Number of species in summer, all areas	112
Number of species in autumn, all areas	100
Species in spring only, all areas	26
Species in summer only, all areas	19
Species in autumn only, all areas	12
Number of species in beech-maple only, all seasons	30
Number of species in oak-hickory only, all seasons	64
Number of ferns	3
Annuals, percent of total	9
Perennials	91

TABLE II

Seasonal distribution of species in the two forest-types

	Spring	Summer	Autumn
Species in beech-maple only	18	20	17
Species in oak-hickory only	35	37	33
Total number in beech-maple	53	62	60
Total number in oak-hickory	73	85	72

TABLE III

Species with highest frequency and seasonal distribution

OAK-HICKORY

Species	Spring	Summer	Autumn
<i>Antennaria plantaginifolia</i>	11	12	14
<i>Cunila origanoides</i>	26	31	33
<i>Carex picta</i>	32	36	33
<i>Desmodium rotundifolium</i>	1	22	21
<i>Krigia biflora</i>	15	14	10
<i>Panicum dichotomum</i>	4	30	28
<i>Potentilla simplex</i>	30	31	30

BEECH-MAPLE

<i>Claytonia virginica</i>	15	—	—
<i>Dentaria heterophylla</i>	15	—	—
<i>Dentaria laciniata</i>	34	—	—
<i>Galium concinnum</i>	27	28	27
<i>Smilacina racemosa</i>	11	12	12

TABLE IV

Species with greatest density and seasonal distribution

OAK-HICKORY

Species	Spring	Summer	Autumn
<i>Antennaria plantaginifolia</i>	72	96	77
<i>Carex picta</i>	65	87	84
<i>Cunila origanoides</i>	66	90	100
<i>Desmodium rotundifolium</i>	10	85	75
<i>Krigia biflora</i>	86	116	32
<i>Panicum dichotomum</i>	6	60	49
<i>Polygonatum pubescens</i>	67	17	—
<i>Potentilla simplex</i>	98	103	102

BEECH-MAPLE

<i>Arisaema triphyllum</i>	61	143	16
<i>Carex albursina</i>	—	42	20
<i>Claytonia virginica</i>	81	—	—
<i>Dentaria heterophylla</i>	58	—	—
<i>Dentaria laciniata</i>	99	—	—
<i>Galium concinnum</i>	289	208	164
<i>Pilea pumila</i>	2	28	43
<i>Smilacina racemosa</i>	37	35	27

TABLE V

Showing species which sometime during the growing season show a fidelity of 50% or more.

Species	OAK-HICKORY		
	Spring	Summer	Autumn
<i>Antennaria plantaginifolia</i>	55	55	55
<i>Carex picta</i>	88	88	88
<i>Cunila origanoides</i>	55	77	77
<i>Desmodium rotundifolium</i>	11	66	77
<i>Galium circaezans</i>	44	55	55
<i>Helianthus microcephalus</i>	11	66	33
<i>Hieracium gronovii</i>	33	55	55
<i>Krigia biflora</i>	66	44	33
<i>Lespedeza nuttallii</i>	—	33	55
<i>Panicum dichotomum</i>	33	88	88
<i>Potentilla simplex</i>	77	77	88
<i>Prenanthes altissima</i>	55	55	11
<i>Lysimachia quadrifolia</i>	—	—	66
BEECH-MAPLE			
<i>Anemonella thalictroides</i>	62	50	12
<i>Arisaema triphyllum</i>	50	87	37
<i>Carex albursina</i>	—	75	75
<i>Claytonia virginica</i>	62	—	—
<i>Dentaria laciniata</i>	100	—	—
<i>Desmodium nudiflorum</i>	—	62	37
<i>Galium concinnum</i>	100	87	100
<i>Pilea pumila</i>	12	50	37
<i>Prenanthes altissima</i>	50	12	12
<i>Smilacina racemosa</i>	62	50	75

TABLE VI

Density and frequency of dominants in the arboreal layer of stands included in study of herbaceous layer.

Species	OAK-HICKORY		BEECH-MAPLE	
	Stems	F. I.	Stems	F. I.
<i>Acer saccharum</i>	628	61	1,062	83
<i>Fagus grandifolia</i>	38	13	590	82
<i>Quercus alba</i>	300	55	52	18
<i>Q. borealis maxima</i>	58	24	41	16
<i>Q. montana</i>	671	50	76	9
<i>Q. muhlenbergia</i>	75	24	2	1.5
<i>Q. velutina</i>	456	60	23	10
<i>Carya cordiformis</i>	16	8	39	8
<i>C. glabra</i>	291	50	143	38
<i>C. ovata</i>	168	55	123	31

TABLE VII

Average number of trees for each ten by ten meter quadrat including trees at least three feet in height.

Species	OAK-HICKORY	BEECH-MAPLE
<i>Acer saccharum</i>	4.6	6.3
<i>Fagus grandifolia</i> .....	.28	1.2
<i>Quercus</i> (all species)	11.5	1.1
<i>Carya</i> (all species)	3.5	1.8

TABLE VIII
Frequency, Density and Fidelity of all Herbaceous Species

	BEECH-MAPLE						OAK-HICKORY					
	Spring			Summer			Autumn			Spring		
	FI ¹	D ²	F ³	FI	D	F	FI	D	F	FI	D	F
<i>Acalypha rhomboidea</i>.....	..	..	..	2	22	25	2	12	25	..	..	..
<i>Adiantum pedatum</i>	1	3	12	4	9	25	4	8	25	..	..	..
<i>Agrimonia parviflora</i>.....	..	..	..	..	..	..	..	..	..	..	..	..
<i>A. rostellata</i>	7	54	12	9	52	12	7	34	12	..	..	..
<i>Agrostis</i> sp?.....	..	..	..	..	..	..	7	34	12	1	6	11
<i>A. perennans</i>.....	..	..	..	..	..	..	..	..	..	..	..	..
<i>Ambrosia artemisiifolia</i>.....	..	..	..	..	..	..	..	..	..	..	2	3
<i>Amphicarpa bracteata</i>.....	..	..	..	1	6	12	2	7	25	2	2	22
<i>A. b. comosa</i>	4	12	25	2	5	25	..	..	..	..	..	..
<i>Anemonella thalictroides</i>	11	22	62	5	16	50	2	3	12	..	..	..
<i>Antennaria plantaginifolia</i>.....	..	..	..	1	1	12	1	2	12	11	72	55
<i>Aquilegia canadensis</i>.....	..	..	..	..	..	..	..	..	..	1	1	11
<i>Aralia racemosa</i>	1	1	12	2	2	25	1	1	12	..	..	..
<i>Arisaema triphyllum</i>	11	61	50	19	143	87	7	16	37	..	..	..
<i>Aster</i> sp?.....	1	1	12	..	..	..	2	3	25	6	6	33
<i>A. cordifolius</i>.....	..	..	..	..	..	..	..	..	..	..	..	..
<i>Aureolaria flava</i>.....	..	..	..	..	..	..	..	..	..	3	9	22
<i>Bidens</i> sp?.....	..	..	..	1	1	12	1	1	12	..	..	..
<i>Botrychium virginianum</i>	5	9	37	6	14	37	4	6	25	1	1	11
<i>Brachyelytrum erectum</i>	1	5	12	..	..	..	..	..	..	1	10	11
<i>Camassia scillioides</i>.....	..	..	..	..	..	..	..	..	..	1	4	11
<i>Carex</i> sp?.....	26	81	100	17	64	62	14	36	62	13	28	66
<i>C. albusina</i>.....	..	..	..	15	42	75	10	20	75	..	..	..
<i>C. picta</i>	1	1	12	1	1	12	7	27	37	32	65	88
<i>Cassia nictitans</i>.....	..	..	..	..	..	..	..	..	..	1	1	11

TABLE VIII—(Continued)

	BEECH-MAPLE						OAK-HICKORY					
	Spring			Summer			Autumn			Spring		
	F ¹	D ²	F ³	F ¹	D	F	F ¹	D	F	F ¹	D	F
Caulophyllum thalictroides.....	..	..	..	1	1	12	..	..	..	..	..	..
Chenopodium albidum.....	..	..	..	..	..	..	..	..	..	1	6	11
Chimaphila maculata.....	..	..	..	..	..	..	..	..	..	1	1	11
Claytonia virginica.....	15	81	62	..	..	..	..	..	..	1	3	11
Collinsonia canadensis.....	..	..	..	1	5	12	1	5	12	..	..	..
Cunila origanoides.....	..	..	..	..	..	..	..	..	..	26	66	55
Cynoglossum virginianum.....	..	..	..	..	..	..	..	..	..	..	..	..
Danthonia spicata.....	..	..	..	2	2	12	..	..	..	1	8	11
Dasistoma macrophylla.....	..	..	..	..	..	..	..	..	..	1	5	11
Daucus carota.....	..	..	..	..	..	..	1	2	12	..	..	..
Delphinium tricornne.....	..	..	..	..	..	..	..	..	..	8	21	11
Dentaria heterophylla.....	15	58	37	..	..	..	..	..	..	..	..	..
D. laciniata.....	34	99	100	..	..	..	..	..	..	10	44	11
Desmodium sp?.....	4	3	25	2	9	12	1	2	12	..	..	..
D. acuminatum.....	4	7	12	2	6	12	4	4	12	..	..	..
D. nudiflorum.....	..	..	..	10	15	62	5	10	37	..	..	..
D. pauciflorum.....	..	..	..	..	..	..	2	4	25	..	..	..
D. rotundifolium.....	..	..	..	..	..	..	..	..	..	1	10	11
Dioscorea quaternata.....	2	3	25	2	4	12	1	2	12	1	2	11
D. villosa.....	1	1	12	1	1	12	2	3	12	..	..	..
Epifagus virginiana.....	..	..	..	1	1	12	11	25	37	..	..	..
Erechtites hieracifolia.....	..	..	..	..	..	..	..	..	..	..	..	..
Erigeron pulchellus.....	..	..	..	..	..	..	..	..	..	..	..	..
Erythronium americanum.....	1	4	12	..	..	..	..	..	..	1	1	11
Eupatorium maculatum.....	..	..	..	..	..	..	..	..	..	..	..	..
E. urticaefolium.....	4	5	25	9	10	50	2	4	25	..	..	..

TABLE VIII—(Continued)

	BEECH-MAPLE						OAK-HICKORY					
	Spring			Summer			Autumn			Spring		
	FI ¹	D ²	F ³	FI	D	F	FI	D	F	FI	D	F
<i>Galium aparine</i>	2	7	25	..	..	..	..	..	..	6	21	11
<i>G. circaezans</i>	10	20	37	11	21	25	4	4	25	4	8	44
<i>G. concinnum</i>	27	289	100	28	208	87	27	164	100	7	28	33
<i>Geum canadense</i>.....	..	..	..	..	..	..	1	2	12	..	..	..
<i>G. virginianum</i>.....	..	..	..	..	..	..	..	..	..	..	..	..
<i>Geranium maculatum</i>	2	2	25	1	1	12	..	..	..	1	1	11
<i>Gillenia stipulata</i>.....	..	..	..	..	..	..	..	..	..	..	..	..
<i>Gnaphalium</i> sp?.....	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hackelia virginiana</i>.....	..	..	..	1	1	12	1	1	12	..	..	..
<i>Helianthus</i> sp?.....	..	..	..	..	..	..	..	..	..	4	13	22
<i>Helianthus decapetalus</i>.....	..	..	..	..	..	..	..	..	..	..	..	..
<i>H. microcephalus</i>.....	..	..	..	..	..	..	..	..	..	1	1	11
<i>Hedeoma pulegioides</i>.....	..	..	..	5	22	25	2	20	25	..	..	..
<i>Heuchera americana</i>.....	..	..	..	..	..	..	1	1	12	..	..	..
<i>Hieracium scabrum</i>.....	..	..	..	..	..	..	..	..	..	1	1	11
<i>H. gronovii</i>.....	..	..	..	..	..	..	..	..	..	6	11	44
<i>H. paniculatum</i>.....	..	..	..	..	..	..	..	..	..	2	4	11
<i>H. purpurea</i>.....	..	..	..	1	1	12	2	2	25	..	..	..
<i>Hybanthus concolor</i>	1	1	12	1	1	12	..	..	..	..	..	..
<i>Hydrophyllum appendiculatum</i>.	..	..	..	2	2	25	..	..	..	..	..	..
<i>H. macrophyllum</i>	1	3	12	..	..	..	..	..	..	4	21	11
<i>Impatiens pallida</i>	4	13	25	2	6	12	2	5	12	..	..	..
<i>Jeffersonia diphylla</i>.....	..	..	..	..	..	..	..	..	..	5	12	11
<i>Krigia biflora</i>	2	3	12	2	8	12	1	2	12	15	86	66
<i>Lactuca</i> sp?.....	..	..	..	2	2	12	1	1	12	..	..	..
<i>Leersia virginica</i>.....	..	..	..	1	18	12	1	8	12	..	..	..

TABLE VIII—(Continued)

	BEECH-MAPLE						OAK-HICKORY											
	Spring			Summer			Autumn			Spring			Summer			Autumn		
	FI ¹	D ²	F ³	FI	D	F	FI	D	F	FI	D	F	FI	D	F	FI	D	F
<i>Lespedeza</i> sp?.....	..	..	..	..	..	..	2	2	25	..	..	..	..	..	..	2	2	22
<i>L. hirta</i>.....	..	..	..	..	..	..	..	..	..	1	3	11	..	..	..	1	3	11
<i>L. intermedia</i>.....	..	..	..	..	..	..	1	1	12	..	..	..	..	..	..	4	6	33
<i>L. nuttallii</i>.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	12	33
<i>Lithospermum latifolium</i>.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	11
<i>Luzula campestris</i>.....	..	..	..	..	..	..	..	..	..	3	9	22	..	..	..	2	29	22
<i>Lysimachia quadrifolia</i>.....	..	..	..	..	..	..	..	..	..	3	5	33	..	..	..	9	14	44
<i>Mertensia virginica</i>.....	..	..	..	..	..	..	..	..	..	1	17	11	..	..	..	..	..	..
<i>Monarda clinopodia</i>	1	1	12	..	..	..	..	..	..	..	..	..	..	..	..	2	4	22
<i>Muhlenbergia</i> sp?.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Orchis spectabilis</i>	1	2	12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Oxalis</i> sp?.....	..	..	..	2	4	25	1	2	12	..	..	..	..	..	..	1	8	11
<i>O. europea</i>	1	5	12	1	9	12	..	..	..	..	..	..	..	..	..	..	..	..
<i>O. stricta</i>.....	..	..	..	..	..	..	2	2	25	..	..	..	..	..	..	2	7	22
<i>O. violacea</i>.....	..	..	..	..	..	..	..	..	..	4	57	22	..	..	..	..	..	..
<i>Panax quinquefolia</i>	1	1	12	..	..	..	..	..	..	..	..	..	1	1	11	..	..	..
<i>Panicum</i> sp?.....	..	..	..	1	2	12	..	..	..	11	14	44	..	..	..	..	..	..
<i>P. boscii</i>	2	4	12	2	2	12	4	4	12	..	..	..	..	..	..	5	13	44
<i>P. dichotomum</i>.....	..	..	..	..	..	..	..	..	..	4	6	33	..	..	..	30	60	88
<i>P. microcarpon</i>.....	..	..	..	..	..	..	..	..	..	1	1	11	..	..	..	..	..	..
<i>Paronychia canadensis</i>.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	3	22
<i>Phlox bifida</i>.....	..	..	..	..	..	..	..	..	..	..	5	33	..	..	..	4	7	33
<i>P. divaricata</i>	1	1	12	1	2	12	..	..	..	3	5	..	..	..	..	5	6	22
<i>Pilea pumila</i>	1	2	12	7	28	50	9	43	37	..	..	..	..	..	..	..	..	..
<i>Pheopteris hexagonoptera</i>	1	1	12	4	18	12	4	16	12	..	..	..	..	..	..	..	..	..
<i>Plantago</i> sp?.....	..	..	..	..	..	..	1	1	12	..	..	..	..	..	..	..	..	..

TABLE VIII—(Continued)

	BEECH-MAPLE				OAK-HICKORY									
	Spring		Summer		Autumn		Spring		Summer		Autumn			
	FI ¹	D ²	FI	D	FI	D	FI	D	FI	D	FI	D	FI	D
<i>Poa</i> sp?.....	..	..	..	..	..	..	2	5	..	..	..	..	..	..
<i>P. compressa</i>.....	..	..	..	..	2	4	..	..	1	1	1	1	1	1
<i>P. pratensis</i>.....	..	..	1	3	12	..	..	..	..	..	..	..	..	..
<i>Podophyllum peltatum</i>	7	27	25	..	..	..	1	1	..	..	..	..	..	..
<i>Polygonatum pubescens</i>	2	9	25	1	1	12	7	67	4	17	22	..	..	..
<i>Polygonum</i> sp?.....	..	..	1	1	12	..	..	..	..	..	..	..	..	..
<i>P. hydropiper</i>	1	1	12	..	..	..	..	..	..	..	..	..	..	..
<i>P. virginianum</i>.....	..	..	..	..	1	1	..	..	..	..	..	..	..	..
<i>P. scandens</i>.....	..	..	..	..	..	..	..	..	1	1	11	1	1	12
<i>Polystichum acrosticoides</i>	1	2	12	1	3	12	..	..	..	..	..	..	..	..
<i>Potentilla simplex</i>	1	6	12	2	6	25	30	98	31	103	77	30	102	88
<i>Prenanthes altissima</i>	5	9	50	1	3	12	8	21	7	7	55	1	1	11
<i>Ruellia strepens</i>.....	..	..	..	..	..	..	..	..	1	3	11	..	..	..
<i>Sanguinaria canadensis</i>	1	2	12	1	2	12	..	..	..	..	..	..	..	..
<i>Sanicula</i> sp?.....	3	10	37	..	2	6	4	4	..	..	..	..	..	..
<i>S. canadensis</i>.....	..	..	10	15	75	2	4	12	..	2	13	5	9	33
<i>Scutellaria incana</i>.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>S. versicolor</i>.....	..	..	..	..	..	..	1	1	1	1	..	1	1	11
<i>Senecio obovatus</i>	1	3	12	1	4	12	1	3	12	1	4	1	3	11
<i>Silene</i> sp?.....	1	3	12	..	..	..	..	..	..	..	..	..	..	..
<i>Silene stellata</i>.....	..	..	1	1	12	..	..	..	..	..	..	..	..	..
<i>Smilacina racemosa</i>	11	37	62	12	35	50	2	3	22	3	4	1	1	11
<i>Smilax herbacea</i>.....	..	..	..	..	1	1	1	1	11	..	..	..	..	..
<i>Solidago bicolor</i>.....	..	..	..	..	..	..	3	4	11	7	12	44	3	8
<i>S. caesia</i>	4	7	25	..	2	7	7	11	44	7	9	44	7	8
<i>S. juncea</i>.....	..	..	..	..	..	..	..	..	2	2	22	5	7	22

TABLE VIII—(Continued)

	BEECH-MAPLE				OAK-HICKORY			
	Spring		Summer		Spring		Summer	
	FI ¹	D ²	FI	D	FI	D	FI	D
			F ³	F	F	F	F	F
<i>S. latifolia</i>.....	..	..	..	1 2 12	1 2 12	..	..	..
<i>S. nemoralis</i>.....	..	..	..	..	..	..	5 6 33	3 4 33
<i>S. sphacelata</i>.....	..	..	..	..	..	5 7 44	4 5 33	8 10 44
<i>S. ulmifolia</i>.....	..	..	..	..	..	..	10 14 44	5 7 33
<i>Solanum nigrum</i>.....	..	..	..	..	..	..	1 1 11	..
<i>Sphenopholis pallens</i>.....	..	..	..	1 5 12	..	..	1 1 11	..
<i>Stellaria pubera</i>	1	1 12	..	..	..	..	..	..
<i>Taraxacum palustre vulgare</i>...	..	..	..	..	..	..	1 1 11	..
<i>Thaspium trifoliatum flavum</i> ...	4	3 37	..	..	..	1 1 11	..	..
<i>Trillium recurvatum</i>	1	7 12	1	1 12	..	1 4 11	..	..
<i>T. sessile</i>.....	..	..	..	..	..	2 6 11	..	..
<i>Triosteum angustifolium</i>.....	..	..	..	..	..	1 1 11	1 1 11	2 2 11
<i>T. aurantiacum</i>.....	..	..	..	..	..	1 2 11	..	1 1 11
<i>Urtica</i> sp?.....	..	..	..	2 2 12	1 1 12	..	..	1 1 11
<i>Uvularia grandiflora</i>	2	14 12	2	9 12	2 4 12	..	..	..
<i>Viola</i> sp?.....	1	1 12	13 16 50	7 12 62	4 5 44	4 5 44	10 17 66	5 8 44
<i>V. palmata</i>.....	..	..	..	1 3 12	1 2 12	..	..	..
<i>V. papilionacea</i>	22	6 25	1	2 12	4 6 12	2 2 22	2 5 11	..
<i>V. eriocarpa</i>	2	5 12	4 7 12	7 26 22	3 7 11	..
<i>V. triloba</i>	10	16 25	1	2 12

¹FI—Frequency.²D—Density.³F—Fidelity.

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WHAT IS CLIMAX IN CENTRAL INDIANA? A FIVE-MILE QUADRAT STUDY

By J. E. POTZGER AND RAY C. FRIESNER

Indiana offers interesting and frequently puzzling problems to the student of plant life because of the delicate state of equilibrium between geological, climatological and biological phenomena. If we add to this complex a location which borders on several different climatic belts together with the presence within the state of three different physiographic sections, variations and modifications in habitat are multiplied still more. Unless one has spent much time in the field in analytical studies and has struggled with such a tapestry of life and habitat one may become lost in the maze and resort to erroneous generalizations. Since Indiana is outstanding in so many merging phenomena which are sensitively balanced, any description of our forests which does not take this into consideration can only approximate in a general way the true status of affairs in our forest distribution. The present paper is an initial step in an extensive study of Indiana forests on the basis of quantitative field data.

METHODS

The areas studied involved parts of Franklin, Bartholomew, Monroe, Brown and Morgan counties occurring in an east-west line near the northern part of the southern half of the state. Most of the areas studied were unglaciated and those which were glaciated were topographically similar to the unglaciated areas in that more or less dissected ridges or plateaus alternated with steep slopes leading into river valleys.

Sampling was by aid of 10-meter quadrats. The quadrats if placed end to end would total a distance of 5.5 miles. DBH. measurements were made of all trees which were one inch or more in diameter. All stems of woody species at least a meter or more in height were included in the density tabulation. It was assumed that such young trees would not only give information on reproduction but also present a more accurate picture of probable success of reproduction over a longer period of years.

The tabulations were made in winter when the crown cover of leaves could not become an obscuring factor. Previous observa-

tions had shown that two types of associations of the deciduous forest, i. e. *Quercus-Carya* and *Acer-Fagus* were largely determined in expression by exposure of slope either north or south, and so most of the investigations were centered on such slopes. During 1935 the herb layer of the two types of forest was studied as to frequency, density and fidelity (15). Special atmometer studies as well as soil moisture observations in oak-hickory and beech-maple stands were made in 1934 (8) and all indicate more rigorous conditions in the oak-hickory type of forest. Unfortunately there were comparatively few areas with east, west, and intermediate exposure to be examined.

In the tabulation the trees were divided into five size-classes to add to the diagnostic value of the figures. Fidelity is expressed in percent of representation in any one forest type.

OBSERVATIONS

The observations revealed 73 species which comprised: 34 tall trees, 8 small trees, 15 tall shrubs to small trees, 8 small shrubs, and 8 lianas. Of these 61 were in the *Acer-Fagus* type of forest on north-facing slopes. This was also the largest number of species for any exposure group. Forests on south-facing slopes were second with 58 species. All other exposure groups had considerably less, but this may be due partially to a reduced number of quadrats involved in their tabulation. Tall trees made up more than 50% of the total number of woody species present.

Carya glabra is the only species in the tall tree class which has a high fidelity in all exposure groups, and *Sassafras* holds the same distinction for the small tree group, but *Cornus florida* has a higher percentage fidelity in six of the seven groups. *Viburnum acerifolium* is the most widely distributed small shrub. Less than half of the tall trees had a frequency (F. I.) of 50% or above, and none had so high a percentage in all groups. *Acer saccharum* and *Carya glabra* came nearest having a high F. I. in six out of the seven exposure groups. *Acer saccharum* indicated the widest range of potentiality with respect to soil moisture, since it had a high F. I. even on dry ridge-top stands. *Fagus* has a high F. I. only in the more humid north and east exposure locations, while *Quercus velutina* is similarly represented in the dry locations.

No species of *Quercus* or *Carya* go beyond an F. I. of 37% on north-facing slopes. *Ostrya* and *Sassafras* show the highest density

and frequency on the drier sites while *Cornus florida* and *Viburnum acerifolium* show no special preference. In the Acer-Fagus type of forest five species have an F. I. of 33% or higher, and in the Quercus-Carya type nine species have a similar position. Only 129 stems were above 20 inches DBH. This would average 23.4 stems per mile strip ten meters wide.

Comparing density of Acer-Fagus and Quercus-Carya as groups (table I) we find that Acer-Fagus has its greatest density on north and northwest exposures while Quercus-Carya has it on south, southeast, and ridge locations. Southwest, southeast, and ridge are definitely Quercus-Carya; north is definitely Acer-Fagus; while east and northwest are evenly balanced. The outstanding characteristic of the forests in the central part of Indiana is the critically balanced Quercus-Carya and Acer-Fagus climaxes.

DISCUSSION

Much has been written during the last two decades on the concept of "association" and forest-cover types, and still they are an elusive something into which a heterogeneous vegetation with merging tendencies can be pressed only imperfectly. This is especially true of the deciduous forest formation with its abundant species whose potentiality for habitat overlaps, resulting at the border in obliteration or at least in a dimming of a sharply defined segregation of associated species which characterize the association where optimum conditions prevail. Thus *Quercus alba*, *Carya glabra*, and *Carya ovata* may be co-dominant in the weaker expression of the Acer-Fagus association while *Acer saccharum* and *Acer rubrum* may at times constitute an important element in an association otherwise made up of Quercus and Carya. This has led Gleason (9) to the individualistic concept of the association, considering it not a unit which may be found over large geographical locations because of the difference in migration of species which constitute it.

Clements (18) considers the association an entity and attempts to take care of the topographic and geographical variations by the subdivisions of locations and faciations. Cain (5) compares the ecological amplitude of any species to a circle within which a species must move and limits it to its association with other species, and high fidelity is considered a narrow ecological amplitude. *Quercus velutina* is in Indiana the best indicator of the drier-site Quercus-

Carya association and Fagus for the optimum mesophytic Acer-Fagus association.

Cain (5) has pointed out that the complex nature of a climax is indicated by the numerous associations and communities which make up the nomenclature of certain systems. As for our deciduous forest the complex integrating of ecological amplitude circles of various species constituting the crown cover is indicated by the 96 forest cover types adopted for the Eastern United States by the Society of American Foresters (17). Systems of classifications may fail because of unwieldy complexity or because of undiagnostic brevity. The forests of Indiana are typical of the complexity of the eastern deciduous forest and this complexity is mostly due to the physiographic and climatic factors which make Indiana a "critical botanical area" (7). For the same reason even the arboreal layer of the forests of Indiana are so frequently misinterpreted. So Zon (19) in the atlas of American Agriculture and Fenneman (6) in reproducing maps from the atlas place nearly all of Indiana into the Quercus-Carya type of forest. Gordon (11) more recently published a more diversified vegetation map of Indiana, based primarily on empirical observation. To both of these maps we will refer again later.

In all of the counties studied, the two forest types customarily termed Acer-Fagus and Quercus-Carya are sensitively balanced, and in most cases appear to be closer to Acer-Fagus than to Quercus-Carya for *Acer saccharum* has a high fidelity and F. I. in most exposure groups (table I.) No doubt the sharp ridges are the most definitely defined Quercus-Carya habitat.

A study of this nature also reveals many points about the characteristics of the associated species. One is first of all impressed with the large number of woody species constituting a major or minor part in the cover. This is especially true for the tree layer. It was a customary thing that one had to provide at least 45 lines on the tabulation sheet when a survey of 50 quadrats was made in Indiana while a similar survey on Mackinac Island, Michigan, necessitated room for only five to fifteen species. Gleason (10) lists only seven species which played a part in the forest cover in four stands of Acer-Fagus associations in three counties of the upper part of the lower peninsula of Michigan. The present study shows 32 species playing a major or minor role in typical Acer-Fagus associations in south-central Indiana. This indicates at once the

greater complexity of our Indiana *Acer-Fagus* associations and possibilities for wider rangès of variations within the associations.

The fidelity and frequency data (table I) show a sort of border line condition existing between the two associations for all important species, but *Quercus montana*, *Q. velutina*, and *Fagus grandifolia* have a fairly representative F. I. in all exposure groups. It stands out clearly that these two associations are quite distinct when we consider the number of stems for each 100 sq. meters. *Fagus* is represented by much smaller numbers of stems in the *Acer-Fagus* association, but that is mainly due to more prolific reproductions by *Acer saccharum*, so that the high totals of stems for *Acer* are due to abundance of stems less than an inch in diameter.

While the customary term *Acer-Fagus* is used in this paper for the designation of the crown cover in the most mesophytic forest, it should be pointed out that this term must be made very inclusive of many other species which play a part in the crown cover when Indiana forests of this type are considered. Potzger (13) pointed this out in his study in Monroe county, saying that the so-called *Acer-Fagus* is more of a mixed hardwoods type in which *Acer* and *Fagus* play a prominent role. Braun (1) was the first to apply the term "mixed mesophytic" forest to such associations. Sampson (16) described a mixed mesophytic forest for Ohio, which as a whole closely approximated many of the Indiana stands included in this study. In a recent paper Miss Braun (4) discusses at length the three-fold vs. the four-fold concept of climax associations in the eastern deciduous forest. She places the true *Acer-Fagus* association into the northern limits of the deciduous forest, and expresses the opinion that in Indiana the *Acer-Fagus* association is in reality the "mixed mesophytic association." In the present study there are nine tall tree species with a fidelity of 75% or over in fifteen stands on north-facing slopes, which are characterized as *Acer-Fagus* according to the present conception of forest cover types for this region, but only *Acer* and *Fagus* have an F. I. of 50% or over in these stands. Density of tall trees with a DBH. above six inches in the fifteen stands is as follows:

Species	6-10 inches	11-20	Above 20 inches
<i>Fagus</i>	39	70	68
<i>Acer</i>	30	14	11
	—	—	—
The two combined	69	84	79
All other species	262	115	21

This definitely indicates that other species besides *Acer* and *Fagus* play a prominent part in the crown cover, thus supporting the opinion of Miss Braun (4) and Potzger (13) that the most mesophytic forest climax of central Indiana is not a typical *Acer-Fagus* forest whose crown cover is controlled primarily by two species, but rather by a complex of a number of species (in the fifteen stands considered in this paper, by 25 species) *Acer* and *Fagus* have, however, 3.5 times as many stems above 20 inches DBH. as the other 23 species combined, but this may be in part a reflection of selective cutting. In the seedling and small size classes (table I) the 23 species of the association complex are greatly outnumbered by *Acer* and *Fagus*, and if the abundance of reproduction is diagnostic of the crown cover of future years there would be a possibility that a true *Acer-Fagus* crown cover will be the end of succession in the Indiana mixed mesophytic forest.

Quercus-Carya, too, is not so sharply limited to these genera as assumed by the term. In fourteen stands on south-facing slopes, eight tall tree species showed a fidelity of 75% or over and three had an F. I. of 50% or over. Representation according to density is as follows:

Species	6-10 inches	11-20	Above 20 inches
<i>Quercus</i>	418	145	7
<i>Carya</i>	42	13	..
<hr/>			
Combined	460	158	7
All others	95	28	3

Twenty-two species shared in the crown cover control, namely five *Quercus*, three *Carya* and 14 other species, but control was more typical *Quercus-Carya* in these stands than *Acer-Fagus* in the most mesophytic forest. The present study indicates a justification for renaming the classical Indiana "beech-maple association" as the "mixed mesophytic association" in which beech and maple are the most prominent members, for it becomes at once evident to a worker transferring activities from Indiana beech-maple to that of northern Michigan that the association complex in these two areas bearing the same designation are strikingly different.

The *Quercus-Carya* type forest does not have a second layer tree cover so well expressed as the *Acer-Fagus* type has, where *Ostrya*, *Carpinus*, and *Cornus florida* play a prominent part. There is also a big difference in the aerial and edaphic factors between the habitat

sites occupied by the two forest types. South-facing slopes in this same region had 60% more evaporation loss than north-facing slopes while soil had 30% less moisture on south slopes than on north slopes (8). In various parts of Brown and Bartholomew counties *Acer-Fagus* areas registered less water loss than *Quercus-Carya* while soil moisture was always higher in the former (8). Consistent differences in the important species which make up the herbaceous layer in these two types of forest have also been shown (15).

The gradual merging of species constituting the *Acer-Fagus* and *Quercus-Carya* types of forest in intermediate exposures seems to support the opinion expressed previously that Indiana has a sensitively balanced division between forest types. How do the quantitative data of this study agree with the forest type distribution given in the vegetation maps published to date on Indiana forests? In a general way very poorly. As a whole Zon (19) classified the state too dry and Gordon (11) to mesophytic, especially for Bartholomew, Monroe, and Morgan counties. In a complex forest situation such as we have in Indiana, it is impossible even to approximate an accurate analysis of facts for a vegetation map without very extensive quadrat data. Quadrat study is a time-consuming method but will eventually be the only reliable method upon whose results a vegetation map can be based. Not only is Gordon's map inaccurate in the region covered by the present bulky field data, but as McCoy (12) has pointed out, also in the interpretation of the forests of the western lobe of the Illinoian till plain.

Our study showed very little difference in the makeup of *Acer-Fagus* and *Quercus-Carya* types of forest cover in Brown, Monroe, Morgan, Bartholomew counties on the one hand (unglaciaded areas) and those of Franklin county (glaciaded) except that *Quercus velutina* and *Q. montana* were replaced by *Q. alba* and *Q. muhlenbergii*. The prominent place occupied by *Acer saccharum* even in the drier sites may be due to cultural influence, i. e. selective cutting which gave a prolific seeder like *Acer saccharum* an advantage which might be reduced considerably by later competition. This is indicated on the steep slope of area 39 in Franklin county. The small number of trees (129) above 20 inches DBH. in 5.5 miles of quadrats indicates immature forests in central southern Indiana.

SUMMARY AND CONCLUSIONS

1. The paper deals with quantitative data of a 5.5 mile quadrat study of forests in Franklin, Bartholomew, Brown, Monroe and Morgan counties, Indiana.

2. The four strata of these Indiana forests were made up of 73 woody species divided as 34 tall trees, 8 small trees, 15 tall shrubs to small trees, 8 small shrubs and 8 lianas.

3. The forests of these counties were all approximately of the same constitution.

4. North-facing slopes and moist uplands support a modified Acer-Fagus type of forest with 25 species occupying space in the crown cover.

5. South-facing slopes and ridge location are typically *Quercus-Carya*.

6. Intermediate slope-exposure locations support a more mixed mesophytic type of forest.

7. The Acer-Fagus type of forest has a better developed small tree layer than the *Quercus-Carya*.

8. Species constituting the small tree stratum are: *Cornus florida*, *Ostrya virginiana*, *Carpinus caroliniana*, and in more disturbed areas, *Sassafras albidum*.

9. *Viburnum acerifolium* is the most common and widely distributed small shrub.

10. Apparently, the climate favors a modified Acer-Fagus climax and microclimate induced by topography causes and maintains the *Quercus-Carya* forest cover type in Central Indiana.

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TABLE I

Density (D), frequency (FI), fidelity (Fi) and size classes of species on 15 north-facing (N), 14 south-facing (S), 5 west-facing (W), 4 east-facing (E), 2 northwest-facing (NW) and 1 southeast-facing (SE) slopes and 7 ridge (R) exposures.

Species	Ex- posure	SIZE CLASSES					D	FI	Fi
		Below 1"	1- 5"	6- 10"	11- 20"	Above 20"			
<i>Acer nigrum</i>	N	35	..	..	..	..	35	2.0	6.6
	NW	2	..	..	..	..	2	4.1	50
<i>A. rubrum</i>	N	106	76	1	3	..	186	16.8	80
	S	377	228	7	1	..	613	48.2	85.7
	W	122	112	2	..	..	236	55.3	80
	E	25	33	8	..	..	66	36.1	75
	NW	78	52	..	..	..	130	83.3	100
	R	16	85	20	..	..	105	28.7	57.1
<i>A. saccharum</i>	N	2387	822	30	14	11	3274	89.5	100
	S	665	646	4	..	1	1316	57.6	100
	W	120	47	1	..	..	168	39.2	100
	E	109	130	10	2	1	252	82.7	100
	NW	207	77	6	..	..	290	70.8	100
	SE	69	9	..	..	..	78	100	..
	R	104	126	11	..	..	241	55.3	71.4

TABLE I—(Continued)

Species	Ex- posure	SIZE CLASSES					D	FI	Fi
		Below 1"	1- 5"	6- 10"	11- 20"	Above 20"			
<i>Amelanchier canadensis</i>	N	25	5	..	..	..	30	2.8	33.3
	S	58	10	..	..	..	68	18	50
	W	20	5	..	..	..	25	14.8	60
	E	13	..	..	..	..	13	10.3	50
	R	..	3	..	..	..	3	5.3	28.5
<i>Asimina triloba</i>	N	3	..	..	..	..	3	1.0	13.3
	S	19	1	..	..	..	20	1.7	21.4
	E	75	10	..	..	..	85	20.6	50
	NW	2	..	..	..	..	2	4.1	50
<i>Aesculus glabra</i>	S	12	29	2	..	..	43	6.7	7
	W	1	..	..	..	..	1	1	20
<i>Benzoin aestivalis</i>	N	139	..	..	..	..	139	7.1	60
	S	36	..	..	..	..	36	2.1	21.4
	E	165	..	..	..	..	165	20.6	75
	W	2	..	..	..	..	2	4.1	50
<i>Carpinus caroliniana</i>	N	240	142	6	..	..	388	22.3	60
	S	8	7	..	..	..	15	3.8	35.5
	W	33	4	..	..	..	37	10.6	40
	E	8	5	..	..	..	13	12	75
	NW	5	..	..	..	..	5	4.1	50
	R	3	1	..	..	..	4	5.3	14.3
<i>Carya cordiformis</i>	N	18	48	17	4	..	87	14.3	40
	S	3	13	3	..	..	19	5.9	28.4
	E	1	1	1	..	..	3	5.1	50
	NW	..	1	..	..	..	1	4.1	50
	R	1	..	..	..	..	1	1.8	14.3
<i>C. glabra</i>	N	138	120	19	15	1	293	37.0	100
	S	462	199	16	..	..	677	57.6	100
	W	207	158	7	..	..	372	81.8	100
	E	63	22	10	3	..	98	50	100
	NW	20	57	14	3	..	74	83.3	100
	SE	29	20	..	1	..	50	100	..
	R	100	166	10	..	..	286	81.0	85.7
<i>C. ovata</i>	N	39	120	23	11	..	193	31.6	47
	S	110	114	23	13	..	260	46.1	78
	W	77	58	1	..	..	136	42.5	100
	E	23	1	4	..	..	28	27.5	100
	NW	8	6	1	..	..	15	29	100
	SE	9	5	2	..	..	16	78	..
<i>C. tomentosa</i>	R	19	51	5	..	..	75	45	100
	N	..	2	1	..	..	3	1.0	6.6
	E	1	..	..	..	..	1	1.7	25

TABLE I—(Continued)

Species	Ex- posure	SIZE CLASSES					D	FI	Fi
		Below 1"	1- 5"	6- 10"	11- 20"	Above 20"			
<i>Cercis canadensis</i>	N	29	3	1	..	..	33	4.4	40
	S	38	81	..	..	..	119	6.7	21.3
	W	..	1	..	..	..	1	1.0	20
	E	2	11	..	..	..	13	6.8	25
	NW	..	2	..	..	..	2	4.1	50
	SE	4	..	..	..	..	4	22.0	..
	R	23	10	..	..	..	33	18.0	28.5
<i>Castanea dentata</i>	S	39	15	12	1	..	67	8.4	14.2
	E	..	3	4	..	..	7	8.6	25
<i>Celastrus scandens</i>	N	14	..	..	..	..	14	2.4	27
<i>Celtis occidentalis</i>	N	2	4	1	..	..	7	1.7	27
	S	1	3	..	..	..	4	1.27	14.2
	E	..	1	..	..	..	1	1.7	25
<i>Cornus alternifolia</i>	N	21	..	..	..	..	21	2.8	20
	W	1	..	..	..	..	1	1	20
	E	4	..	..	..	..	4	6.8	25
<i>C. asperifolia</i>	N	3	..	..	..	..	3	0.7	13
	S	48	2	..	..	..	50	4.2	7.1
<i>C. florida</i>	N	431	705	9	..	..	1145	68.5	100
	S	205	157	..	..	..	362	42.3	93
	W	148	132	..	..	..	280	68	100
	E	63	58	..	..	..	121	62	100
	NW	114	72	..	..	..	186	91.7	100
	SE	5	10	..	..	..	15	55	..
	R	105	22	..	..	..	127	55.8	100
<i>Corylus americana</i>	N	74	..	..	..	..	74	1.4	6.6
	S	2	..	..	..	..	2	0.42	7
	W	15	..	..	..	..	15	4.2	40
	R	1	..	..	..	..	1	1.8	14.3
<i>Crataegus</i> sp?	N	2	3	..	..	..	5	1.4	2
	S	5	11	1	..	..	17	5.9	14.2
	R	2	..	..	..	..	2	1.8	14.3
<i>Dirca palustris</i>	S	7	..	..	..	..	7	1.27	7
<i>Diospyros virginiana</i>	R	1	11	..	..	..	12	7.1	57.1
<i>Evonymus atropurpurea</i>	N	6	..	..	..	..	6	0.35	6.6
	S	6	..	..	..	..	6	2.1	14
	E	1	..	..	..	..	1	1.7	25
<i>Fagus grandidentata</i>	N	246	419	39	70	68	846	76.2	100
	S	144	142	17	11	1	314	31.7	78
	W	70	169	19	9	8	276	49.9	80
	E	18	31	13	6	6	73	53.3	75
	NW	4	..	..	..	..	4	12.5	100
	R	7	3	1	1	1	13	14.3	57.1

TABLE I—(Continued)

Species	Ex- posure	SIZE CLASSES					D	FI	Fi
		Below 1"	1- 5"	6- 10"	11- 20"	Above 20"			
<i>Fraxinus americana</i>	N	42	50	7	1	..	100	16.4	53
	S	16	55	16	3	..	90	16.8	28.4
	W	1	2	..	..	..	3	3	20
	E	3	4	..	..	..	7	12	50
	R	1	..	..	..	..	1	1.8	14.3
<i>F. biltmoreana</i>	N	..	..	..	..	1	1	0.35	6.6
<i>F. lanceolata</i>	N	127	34	2	1	..	164	21.4	60
	S	16	5	2	..	..	23	6.7	43
	W	14	4	..	..	..	18	10.6	60
	E	54	18	2	1	..	75	39.5	100
	NW	4	2	..	..	..	6	24	100
	SE	2	9	..	..	..	11	66	..
	R	24	27	2	1	..	54	32	28.5
<i>F. pennsylvanica</i>	N	6	12	..	..	..	18	3.8	33.3
	S	5	2	..	..	..	7	2.5	14.2
	W	5	3	..	..	..	8	5.3	40
	E	20	6	1	..	..	27	24	50
	NW	2	..	..	..	..	2	8.3	100
<i>F. quadrangulata</i>	SE	5	..	..	..	..	5	11	..
	R	12	4	..	..	..	16	14.3	14.3
	N	6	3	..	..	..	9	2	27
	S	36	109	12	1	..	158	21	7
	E	9	1	..	..	..	10	8.6	25
<i>Gaylussacia baccata</i>	S	21	..	..	..	..	21	6.3	7
<i>Gleditsia triacanthos</i>	S	..	2	..	..	..	2	0.42	7
<i>Gymnocladus dioica</i>	S	..	4	..	..	..	4	0.84	7
<i>Hamamelis virginiana</i>	N	103	25	..	..	..	128	8.2	67
	S	61	..	..	..	..	61	8.8	35.5
	W	41	1	..	..	..	42	12.7	80
	E	3	..	..	..	..	3	1.7	25
	NW	52	..	..	..	..	52	25	50
	SE	6	1	..	..	..	7	33	..
	R	6	..	..	..	..	6	7.1	28.5
<i>Hydrangea arborescens</i>	N	79	..	..	..	..	79	8.2	67
	S	18	..	..	..	..	18	12.1	21
	E	8	..	..	..	..	8	3.4	50
	NW	1	..	..	..	..	1	4.1	50
<i>Juglans cinerea</i>	N	1	4	8	4	..	17	4.4	53
	S	3	8	..	..	..	11	3.4	28.4
	W	..	1	..	..	..	1	1	20
	E	2	2	..	..	..	4	5.1	25
<i>J. nigra</i>	N	1	1	1	5	..	8	2.8	33.3
	S	..	2	9	2	..	13	3.8	21
	E	..	..	3	7	..	10	10.3	50
	R	..	3	4	1	..	8	9	14.3

TABLE I—(Continued)

Species	Ex- posure	SIZE CLASSES					D	FI	Fi
		Below 1"	1- 5"	6- 10"	11- 20"	Above 20"			
<i>Juniperus virg. crebra</i>	N	..	1	..	..	..	1	0.35	6.6
<i>Liriodendron tulipifera</i>	N	8	13	35	13	1	70	15.3	75
	S	9	4	..	1	..	14	3.4	21
	E	8	1	2	2	..	13	13.7	50
<i>Morus rubra</i>	N	10	14	3	..	..	27	8.8	67
	S	2	2	..	..	..	4	1.7	21
	E	2	1	..	..	..	3	5.1	50
	R	4	5	..	..	..	9	13.5	28.5
<i>Nyssa sylvatica</i>	N	51	46	5	5	4	109	19	86.6
	S	168	59	2	1	..	230	29.9	85
	W	74	23	1	3	..	101	40.4	80
	E	28	19	..	1	1	49	29.2	75
	NW	48	11	..	1	..	60	70.7	100
	SE	9	1	..	..	..	10	44	..
	R	8	1	..	..	..	9	12.5	28.5
<i>Ostrya virginiana</i>	N	454	462	17	1	..	934	66.4	100
	S	94	138	5	..	..	237	32.6	78
	W	187	51	1	..	..	239	45.5	100
	E	29	36	3	..	..	69	39.5	100
	NW	91	14	..	..	..	105	58.3	100
	SE	12	3	..	..	..	15	44	..
	R	28	27	..	..	..	55	30.5	42.9
<i>Parthenocissus quinquefolia</i>	N	51	..	..	..	..	51	2.4	20
<i>Populus grandidentata</i>	N	1	9	17	..	..	27	3.4	30
	S	1	10	11	1	..	23	4.2	14
	NW	..	10	..	..	..	10	8.3	50
	R	1	..	..	..	..	1	1.8	14.3
<i>Prunus serotina</i>	N	6	1	4	2	1	14	3.4	40
	S	6	..	..	..	..	6	2.1	14
	W	1	1	..	..	..	2	2	40
	E	1	2	..	..	..	3	5.1	50
	NW	2	..	..	..	..	2	8.3	100
	R	1	..	..	..	..	1	1.8	14.3
<i>Quercus alba</i>	N	22	79	23	8	8	140	26.6	75
	S	235	430	76	30	1	772	64	93
	W	45	562	21	7	1	636	75.5	100
	E	28	30	9	4	..	71	34.7	75
	NW	67	22	6	..	..	95	46	50
	SE	30	56	..	..	..	86	89	..
	R	10	27	13	2	1	52	41.3	71.4
<i>Q. borealis maxima</i>	N	6	38	19	32	2	97	21.8	86.6
	S	10	40	21	18	2	91	19.4	50
	W	..	..	2	..	..	2	21	40

TABLE I—(Continued)

Species	Ex- posure	SIZE CLASSES					D	FI	Fi
		Below 1"	1- 5"	6- 10"	11- 20"	Above 20"			
<i>Q. montana</i>	E	..	2	4	1	..	7	6.8	50
	NW	..	..	..	1	..	1	8.3	50
	R	1	..	..	..	..	1	1.8	14.3
	N	62	120	53	..	1	236	10.5	40
	S	321	507	131	6	1	966	34	57
	W	7	159	3	..	..	169	12.7	20
	E	34	52	32	5	..	123	25.8	25
	NW	38	89	38	5	..	170	83.3	100
	SE	15	76	1	..	..	92	100	..
<i>Q. muhlenbergii</i>	R	202	146	39	5	..	382	39.5	57.1
	N	..	1	..	..	2	3	7.0	13
	S	3	38	18	14	2	75	14.3	14
<i>Q. velutina</i>	R	..	2	..	1	..	3	1.8	14.3
	N	19	34	10	6	..	69	13.3	60
	S	138	218	172	77	1	606	60.6	93
	W	45	527	41	34	1	648	47.8	100
	E	1	5	7	5	..	17	17.2	75
	NW	14	10	11	4	..	39	58.3	100
<i>Ribes cynosbati</i>	SE	12	26	2	2	..	42	89	..
	R	20	99	37	30	..	186	87.5	85.7
	N	25	..	..	..	..	25	3.1	33.3
	S	37	..	..	..	..	37	5	7
	W	6	..	..	..	..	6	1	20
	E	26	..	..	..	..	26	5.1	25
<i>Rhus copallina</i>	S	7	..	..	..	..	7	2.1	28
	W	35	8	..	..	..	43	4.2	20
<i>R. glabra</i>	R	10	11	..	..	..	21	14.3	28.5
	E	1	..	..	..	..	1	1.7	25
<i>R. toxicodendron</i>	R	1	..	..	..	..	1	1.8	14.3
	N	8	..	..	..	..	8	2.4	26.6
<i>R. typhina</i>	S	2	..	..	..	..	2	0.84	7
	NW	1	..	..	..	..	1	8.3	50
<i>Rubus allegheniensis</i>	N	8	..	..	..	..	8	1.7	20
	S	1	..	..	..	..	1	.42	7
<i>R. occidentalis</i>	N	1	..	..	..	..	1	.35	6.6
<i>Sambucus canadensis</i>	N	2	..	..	..	..	2	7.0	13.3
	E	2	..	..	..	..	2	3.4	25
<i>Sassafras albidum</i>	N	115	175	36	3	..	329	26.5	86.6
	S	223	169	10	..	..	402	34.4	78
	W	98	218	3	..	..	319	61.6	100
	E	88	13	7	..	..	108	51.6	75
	NW	97	63	3	..	..	163	70.8	100
	SE	20	64	..	..	..	84	89	..
	R	94	69	2	..	..	165	46.7	85.7

TABLE I—(Continued)

Species	Ex- posure	SIZE CLASSES					D	FI	Fi
		Below 1"	1- 5"	6- 10"	11- 20"	Above 20"			
<i>Smilax hispida</i>	N	4	..	..	..	..	4	1	20
<i>S. rotundifolia</i>	N	56	..	..	..	..	56	6.3	20
	W	94	..	..	..	..	94	21.2	100
	E	104	..	..	..	..	104	43	100
	NW	6	..	..	..	..	6	12.5	100
	SE	6	..	..	..	..	6	22	..
	R	49	..	..	..	..	49	36	57.1
<i>Tilia americana</i>	N	27	34	8	..	..	69	6.6	33.3
	S	8	15	..	1	..	24	9.2	14
	W	1	5	..	..	..	6	2.1	40
	E	2	..	..	..	..	2	3.4	50
	NW	1	1	..	..	..	2	4.1	50
	R	1	..	..	..	..	1	1.8	14.3
<i>Ulmus americana</i>	N	5	19	10	2	..	36	8.7	33.3
	S	4	12	5	7	..	24	9.2	14
	W	..	1	..	..	..	1	1	20
	R	..	2	2	..	..	4	5.3	14.3
<i>U. fulva</i>	N	155	11	10	1	..	177	15.7	73.3
	S	100	22	7	..	..	129	9.6	43
	W	26	3	1	..	..	30	10.6	40
	E	149	42	2	..	..	193	43	100
	R	123	18	..	..	..	141	32.3	42.8
<i>U. racemosa</i>	N	3	6	..	2	..	8	1.7	20
<i>Vaccinium stamineum</i>	S	2	..	..	..	..	2	0.42	7
	W	8	..	..	..	..	8	2.1	40
	NW	8	..	..	..	..	..	..	..
<i>V. vacillans</i>	S	6	..	..	..	..	6	1.7	7
	E	1	..	..	..	..	1	1.7	25
<i>Viburnum acerifolium</i>	N	324	..	..	..	..	324	21.3	86.6
	S	269	..	..	..	..	269	29	85
	W	111	..	..	..	..	111	30.8	80
	E	36	..	..	..	..	36	27.5	75
	NW	31	..	..	..	..	31	33.3	100
	R	189	..	..	..	..	189	28.7	42.8
<i>V. prunifolium</i>	N	7	..	..	..	..	7	1	13
	S	10	..	..	..	..	10	0.84	7
<i>Vitis</i> sp?	N	49	..	..	..	..	49	12.2	53.3
	S	11	2	..	..	..	13	3.4	28
	W	18	..	..	..	..	18	13.6	80
	E	25	5	..	..	..	30	27.5	100
	SE	9	..	..	..	..	9	44	..
	R	1	1	..	..	..	2	3.5	14.3
<i>V. aestivalis</i>	N	14	..	..	..	..	14	3.4	13
	S	9	..	..	..	..	9	3.8	7

SOME NECESSARY NOMENCLATORIAL CHANGES IN THE GENUS SOLIDAGO

By RAY C. FRIESNER

While attempting to bring all species and varieties of *Solidago* in North America into one key the necessity for the following name changes became apparent.

SOLIDAGO BOMBYCINUM (Lunell) comb. nov. Originally described by Lunell (Amer. Midl. Nat. 2:59. 1911) from North Dakota as *Oligoneuron*. This latter name is worthy of retention as a subgenus name but the only character by which it can be differentiated from all other subgenera of *Solidago* is the 3-nerved tegules which are often so inconspicuous as to be very uncertain. From the standpoint of a field taxonomist *Oligoneuron* should be kept subordinate to and not coordinate with *Solidago*.

SOLIDAGO CANESCENS (Rydb.) comb. nov. Originally described by Rydberg (Bull. Torr. Bot. Cl. 31:652. 1904) as *Oligoneuron*. Status of this as a subgenus name given in the preceding paragraph.

SOLIDAGO GIGANTEA SALEBROSA (Piper) comb. nov. Originally described by Piper (Fl. Palouse Reg. 185. 1901) as a variety of *S. serotina*. Fernald (Rhodora 49:457. 1939) having shown that *S. serotina* should be reduced to a variety of *S. gigantea* Ait., *S. serotina salebrosa* Piper should therefore be changed to the above new combination.

SOLIDAGO GRAMINEA (Wooten & Standley) comb. nov. Originally described by Wooten and Standley (Contr. U. S. Nat'l. Herb. 16:183, 1913) as *Petradoria*. Maintaining that *Petradoria* should be kept as a subgeneric name the above recombination becomes necessary.

SOLIDAGO texensis (Greene) nom. nov. Originally described by Greene (Pittonia 5:17. 1902) from southeastern Texas as *Euthamia pulverulenta*. If *Euthamia* is to be kept only as of subgeneric rank this would become *Solidago pulverulenta* (Greene), but this name would be invalid because of its prior use for a valid species, viz. *S. pulverulenta* Nutt. (Gen. Am. 2:161. 1818). The above name is therefore proposed as a new name for this species.